HEAVY RAINFALL OVER NORTHEASTERN WYOMING AND SOUTHERN MONTANA, MAY 21, 1952

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INTRODUCTION

On May 21, 1952, 1 to nearly 3 inches of rain fell over a narrow oblong strip of territory extending form Chadron, Nebr. to Billings, Mont. and westward to Bozeman, Mont.

Stations within the belt of heavy rainfall reported steady post-frontal type rain which continued to fall even after the cold front had moved into the eastern portions of Kansas and Nebraska. Outside this area the showers and thunderstorms ceased within a few hours after the frontal passage.

The rainfall in the Dakotas and Montana was preceded by low-level advection of moisture from the Gulf of Mexico northwestward toward the western Dakotas where it was lifted to high altitudes by a developing cyclonic circulation aloft.

SURFACE WEATHER

It was not evident on the 1230 GMT surface chart for May 20, 1952 (fig. 1) that air from the Gulf of Mexico would be drawn northward over the Plains to Montana within 24 hours. The surface pressure configurations in figure 1 suggested that the region of the northwestern Plains should be under the influence of maritime Polar air during the following 24 hours. The weak cold front which had extended southward from north-central Montana had virtually dissipated by 2130 GMT in the vicinity of Sheridan, Wyo.

With the decay of this weak front, another cold front became evident along a line from Great Falls, Mont., to Ely, Nev., at about the time the preceding one was dropped from the analysis. The second cold front was accompanied by numerous showers and thunderstorms by the time it reached western Montana, and the instability type of weather continued as the front moved eastward to the middle Plains States. At 0330 GMT May 21, considerable shower activity was in progress over western Montana when steady rains began to fall at Dubois, Idaho, and Dillon, Mont. During the following day this area of steady rain moved eastward to the location shown by figure 2, the 1230 GMT map for May 21. The cold front shown east of the Divide is the one which had taken form on the previous afternoon.

The establishment of a clearly defined flow of Gulf air moving northward over the Plains States was the most important change to take place from the 20th to the 21st. This came about because of surface deepening which, in turn, was related to increasing cyclonic vorticity aloft as an upper-level jet stream moved southeastward from the State of Washington. The steady rainfall over the Montana–Wyoming region is indicated by the shaded area on the map for 1230 GMT, May 22 (fig. 3). This figure also shows that the flow from the Gulf was still reaching the northern Plains States.

Examination of upper air charts during the period of rain shows that moisture from the Gulf was advected into the region at, or below, the 850-mb. level, whereas, the air flow at the next standard level (700 mb.) was from the west, which was also true of higher levels. It will be noted that there is a similarity between the moist flow at 850 mb., 0300 GMT, May 22 (fig. 4) and the 24-hour precipitation pattern for the period ending 1230 GMT on May 22 (fig. 5).

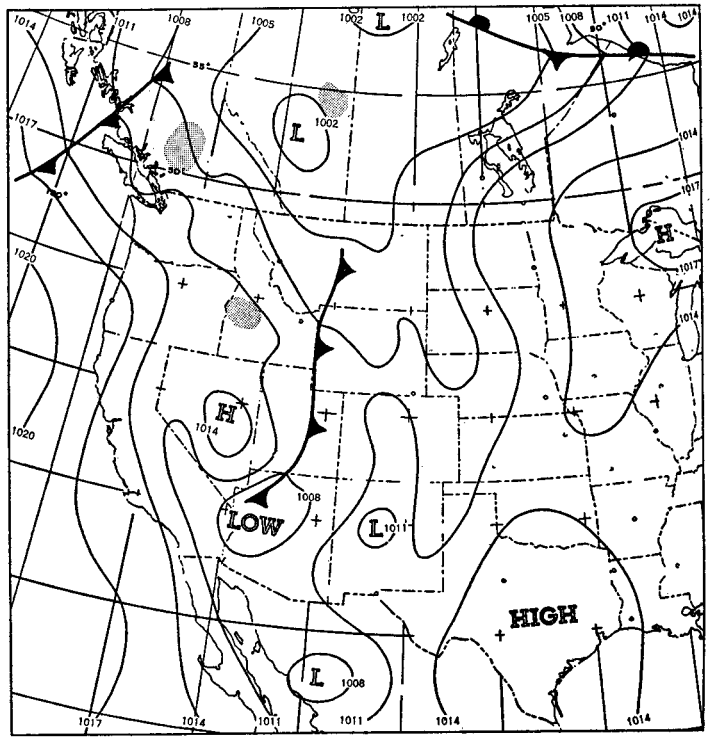

FIGURE 1.—Surface chart, 1230 GMT, May 20, 1952. Shading indicates areas of active precipitation.

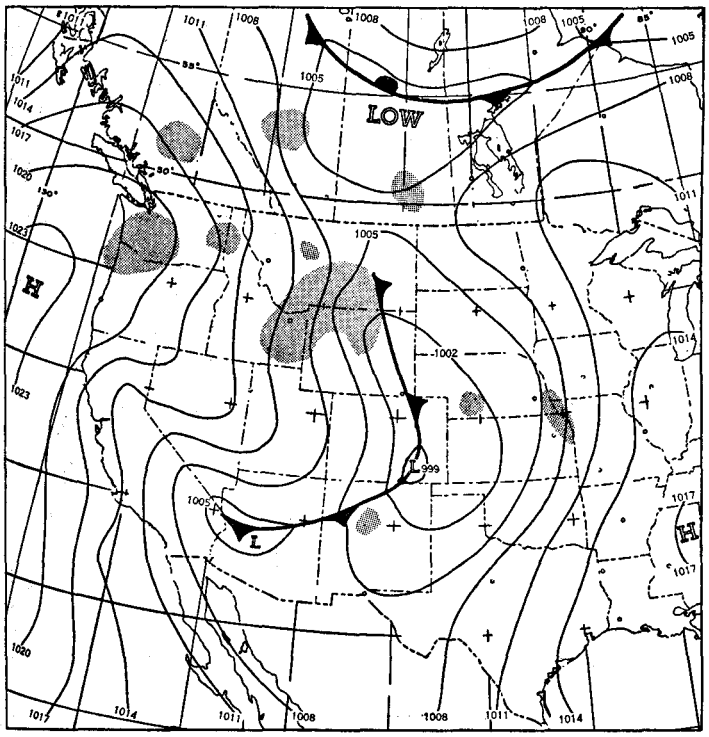

FIGURE 2.—Surface chart, 1230 GMT, May 21, 1952.

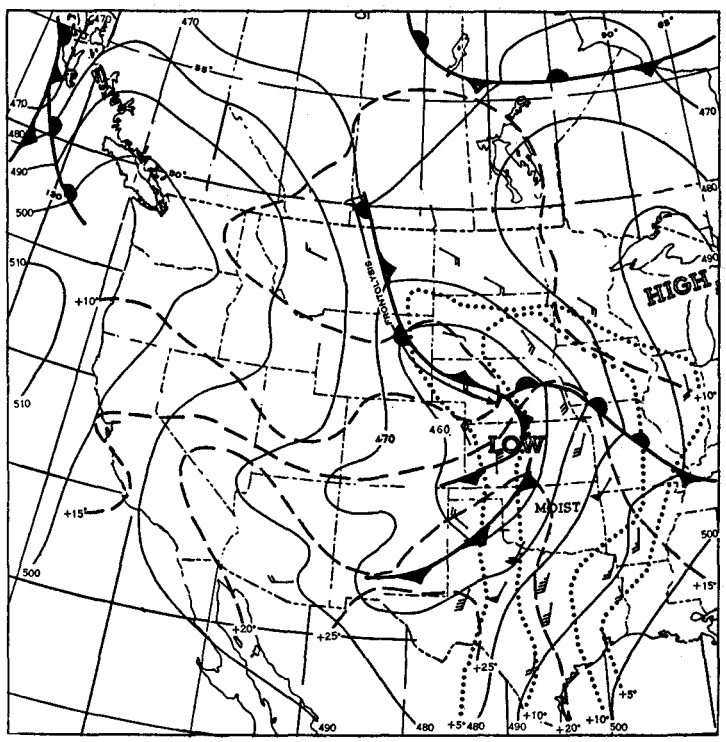

FIGURE 4.—850-mb. chart, 0300 GMT, May 22, 1952. Contours (solid lines) are at intervals of 100 geopotential feet, selected isotherms (dashed lines) at intervals of 5° C., and dew point isotherms (dotted lines) for 5° and 10°C. Barbs on wind arrows are for speeds in knots (pennant=50 knots, full barb=10 knots).

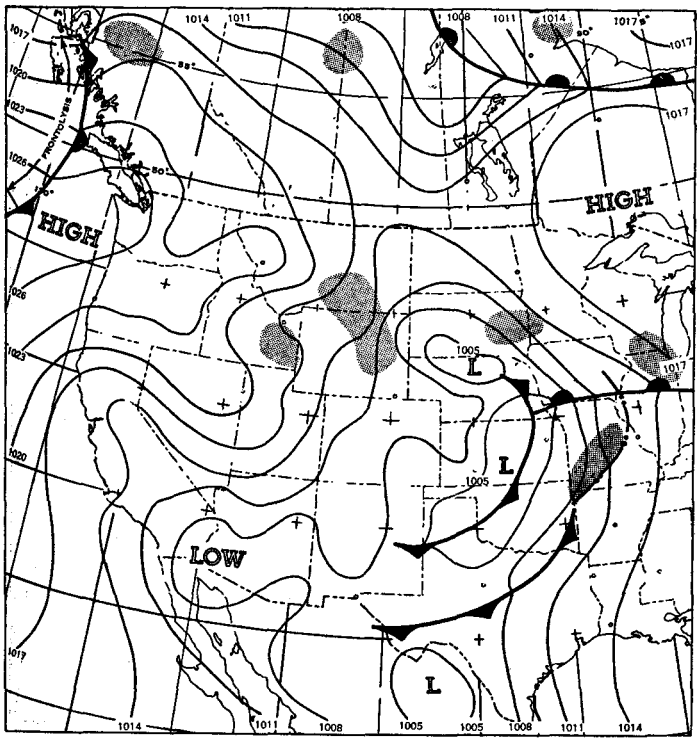

FIGURE 3.—Surface chart, 1230 GMT, May 22, 1952.

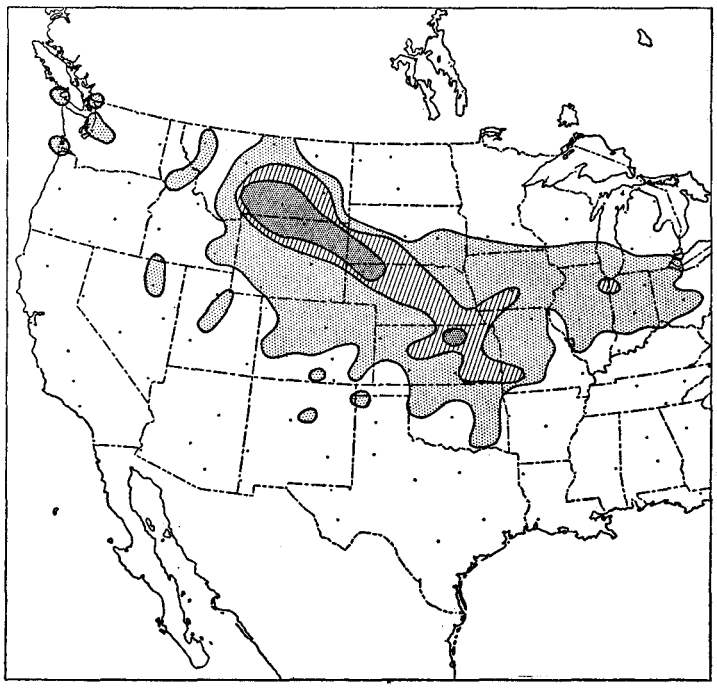

FIGURE 5.—Precipitation chart for 24 hours ending 1230 GMT, May 22, 1952. Light stipple=Trace to less than ½ in., hatching=½ in. to less than 1 in. and heavy stipple=1 in. or more.

EFFECTS OF HIGH LEVEL CIRCULATION

Some possible clues to an explanation of the steady precipitation may be found in an examination of the 300-mb. charts.

For the past year the WBAN Analysis Center has been analyzing the 300-mb. wind field in terms of isotachs (lines of equal wind speed) drawn at 20-knot intervals, and the jet stream (defined as a line of maximum winds along which the speed is equal to or greater than an arbitrary minimum of 50 knots). The 300-mb. charts used in this article (figs. 10–15) are the 0300 and 1500 GMT charts as analyzed in the WBAN Analysis Center, including the jet, but not including the isotachs nor the temperature data. Analysts in the Center make use of a knowledge of the jet and its behavior as a qualitative tool for prognostic work.

At 1500 GMT, May 20 (fig. 10), a Low was located at 51° N., 123° W. just northwest of the State of Washington, and a trough extended due south over western Oregon toward northern California. There was a ridge from Central Canada southward across Wyoming. A residual jet that had moved in from the Pacific was oriented west-to-east across northern California, Nevada, and Utah, while farther upstream, in the vicinity of stationary weather ship "P" (50° N., 145° W.), another jet was moving fairly rapidly toward the southeast. This new wind maximum was apparently associated with a rapidly occluding, deep Low at the surface about 400 miles west-southwest of ship "P".

By 1300 GMT, May 2 (fig. 11), the jet formerly near ship "P" approached the United States-Canadian west coast with a center of maximum wind speed about 300 miles off the coast. Meanwhile the 300-mb. height had risen 400 gpft. in 12 hours near the jet maximum over the ocean and along the United States-Canadian coast. Heights near ship "P" had fallen 300 gpft. with the approach of the deep occluded Low to its west. This increase in heights along the Pacific coast was accompanied by an abundance of warm air advection, in lower levels, ahead of the low pressure system near ship "P". The height difference charts for 1000–700-mb (fig. 6) and 700–500-mb. (fig. 9), 1500 GMT, May 21 indicate intense warm advection.

With this warm high-level ridge development along the Pacific coast the residual jet, with a diminishing speed maximum at the coast, moved eastward and somewhat southward into Nevada. This surge was associated with height falls of 400 to 500 gpft. in eastern Nevada and western Utah and a consequent marked sharpening of the trough over eastern Washington and Oregon. As the Pacific jet maximum approached the coast of Washington the 300-mb. low center moved into central Washington by 0300 GMT (21st) with a trough extending south-southeastward from the low center into northeastern Nevada and northwestern Utah. With this

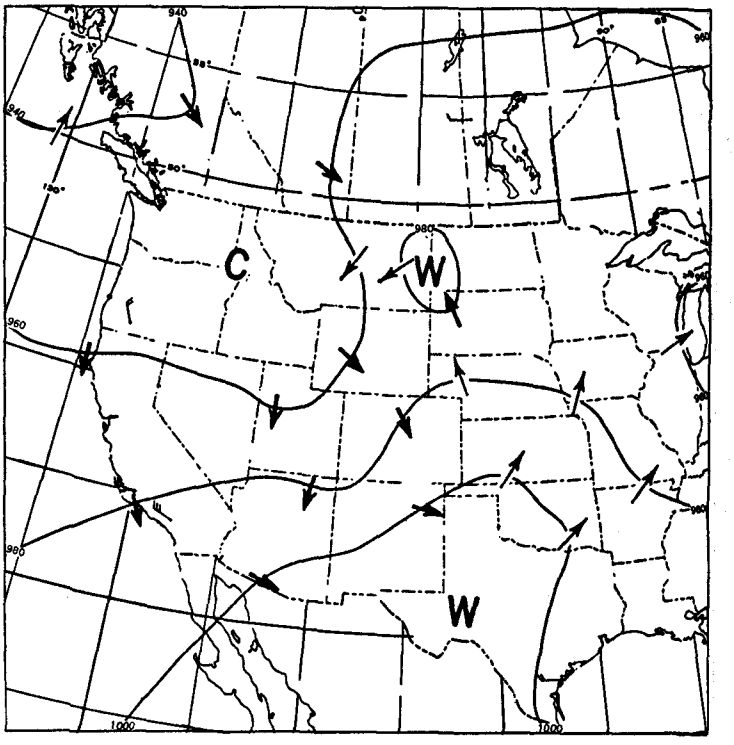

FIGURE 6.—1000—700-mb. height difference chart, 1500 GMT, May 21, 1952. Thickness isolines are drawn at intervals of 200 geopotential feet; warm air advection is indicated by thin arrows and cold air advection by thick arrows. Wind arrows show vector difference (speed in knots) between the two levels. Warm air source is indicated by "W" and cold air source by "C."

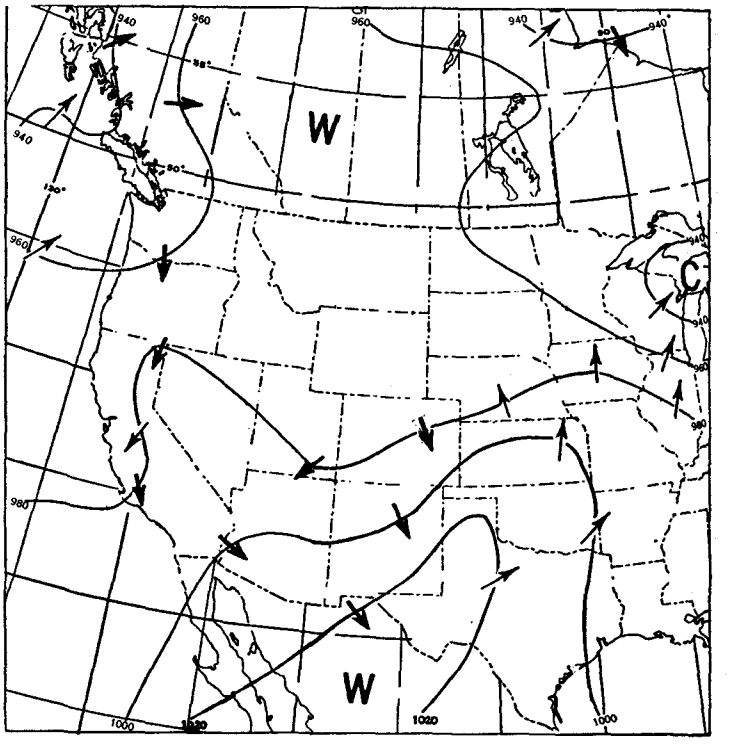

FIGURE 7.—1000—700-mb. height difference chart, 0300 GMT, May 22, 1952.

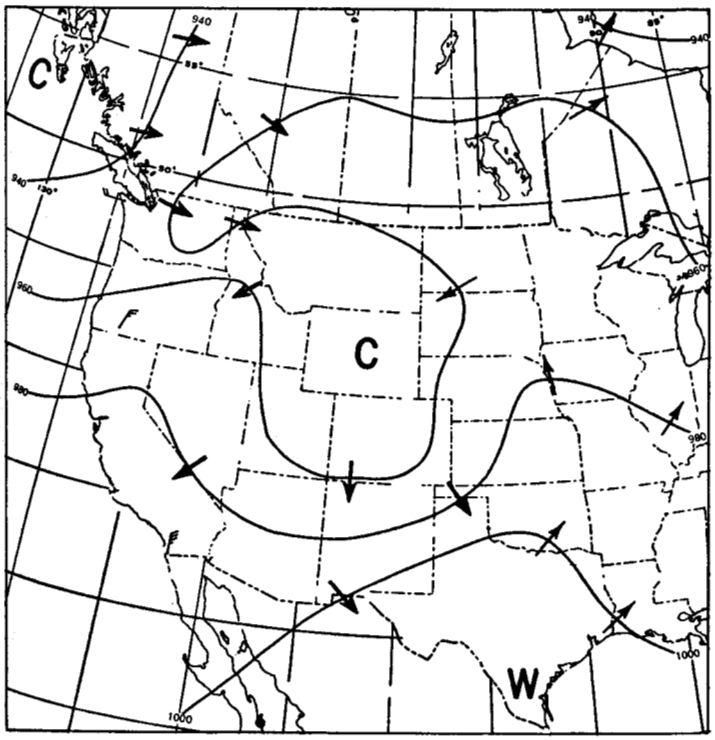

FIGURE 8.—1000—700-mb. height difference chart, 1500 GMT, May 22, 1952.

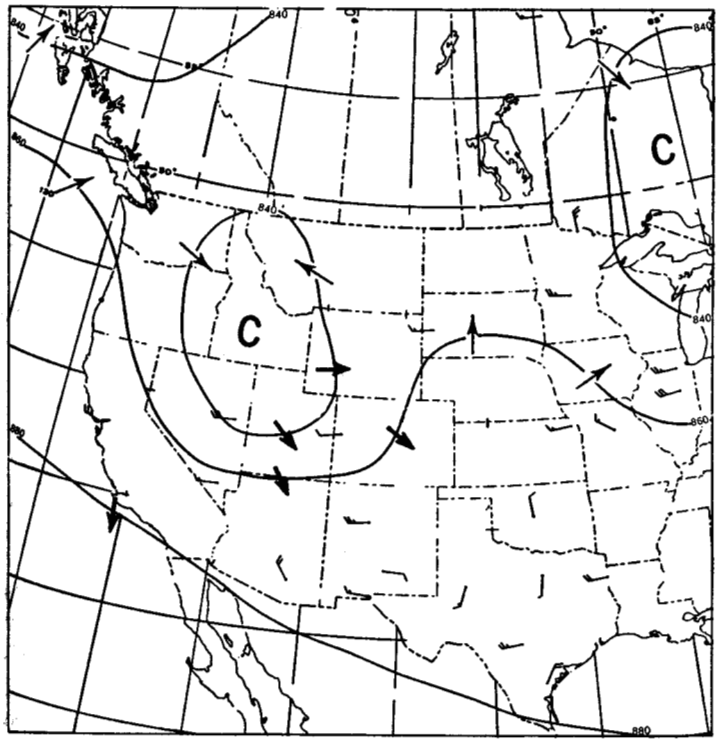

FIGURE 9.—700—500-mb. height difference chart, 1500 GMT, May 21, 1952.

development the winds over Wyoming, Montana, and Utah backed markedly to SW or WSW in conjunction with the appearance of marked diffluence of the 300-mb. contours, considering the contours as streamlines, in and to the east of the trough in northern Nevada, Utah, Wyoming, and southern Montana.

Around midnight of the 20th precipitation began at Billings, first as showers with a cold front passage, then as steady rain for 28 to 30 hours. The continuous rain began a little later at Sheridan, around 0400 MST of the 21st, and continued for 25 hours before becoming intermittent for 8 to 10 hours. The low-level flow at 0300 GMT and 1500 GMT on the 21st (fig. 5) showed warm, moist, tropical air flowing into Wyoming and Montana from the Gulf of Mexico. This warm moist air is shown as warm advection on the height difference charts (figs. 6, 7, 8, and 9).

A shallow, cool, maritime Polar air mass west of the weak cold front and east of the Rockies in Montana and Wyoming moved southeastward and became dammed against the eastern slopes of the Rockies in southern Montana and Wyoming With the southeast drift of the upper-level low center toward Salt Lake City and later to central Colorado, the warm moist Gulf air was forced up over this cooler air mass precipitating its moisture continuously just as if a warm front had existed. After the initial showers over Montana and northern Wyoming, produced by the cold front passage, hourly weather reports showed the precipitation changed to a steady rain over southern Montana and northern Wyoming during the period concerned. Showers and a few scattered thunderstorms existed throughout the period in eastern Utah and Colorado and ended as the upper-level low center moved to the east. Aloft markedly diffluent air flow existed over Montana and Wyoming (fig. 3) as the Low moved southeastward, while there was confluence evident over the central Plain States in warm south-to-southeast low-level flow east of the front (fig. 4). The low-level confluence in the stream of moist Gulf air, as suggested by the wind speeds in figure 4 for example, meant moisture was being lifted to at least the 850-mb. level. Above this level the diffluence over Montana and Wyoming lifted the moisture to greater height by virtue of the vertical shrinking which was taking place at higher levels.

The 300-mb. charts provide some explanation as to why the precipitation continued for such a long time after the cold front passage. If the low center located on the 300-mb. chart for 0300 GMT of the 21st (fig. 11) near central Washington had moved eastward, the period of continuous rain would have been cut short; however, southward or southeastward movement of the upper Low, or deceleration, would tend to prolong the time period; actually the Low moved southeastward and recurved to the east at a very slow rate.

The 300-mb. chart for 0300 GMT, May 21 (fig. 11), shows the Pacific jet (with a maximum of over 95 knots) located at 50° N. 130° W., or about 300 miles west-northwest of Seattle, Wash. After having traveled around the north end of the ridge, it began moving toward the southeast. As previously pointed out, the sharpening of the trough as the residual jet moved into eastern Nevada and western Utah was followed by diffluence at

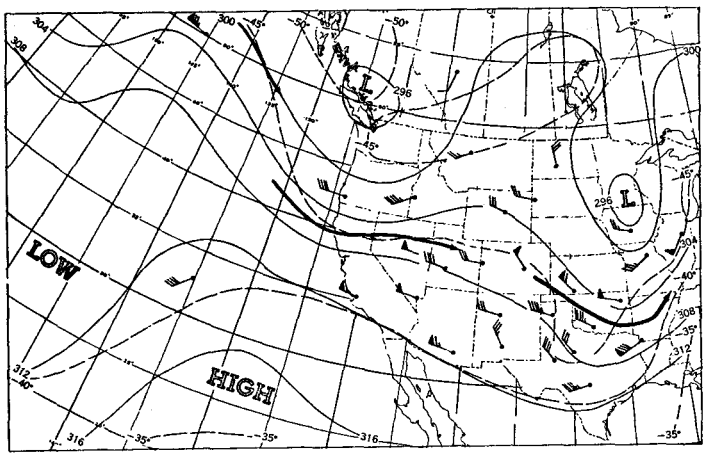

FIGURE 10.—300-mb. chart, 1500 GMT, May 20, 1952. Contours (solid lines) are drawn at intervals of 400 geopotential feet, isotherms (dashed lines) at intervals of 5° C. Barbs on wind arrows are for speeds in knots (pennant=50 knots, full barb=10 knots). Thick black lines ending with an arrow show position of axis of jet stream.

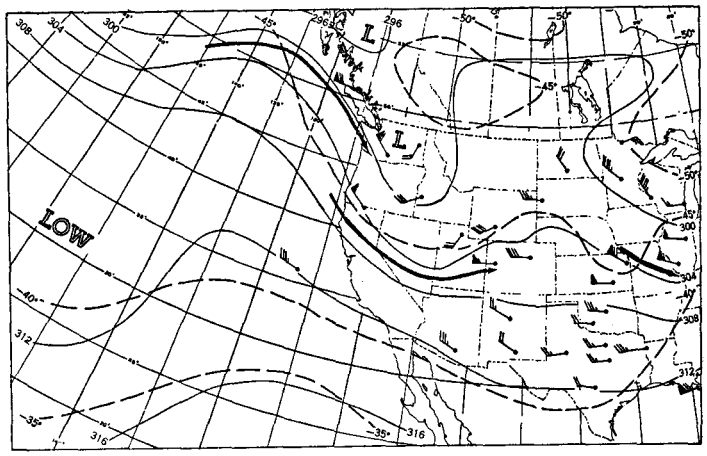

FIGURE 11.—300-mb. chart, 0300 GMT, May 21, 1952.

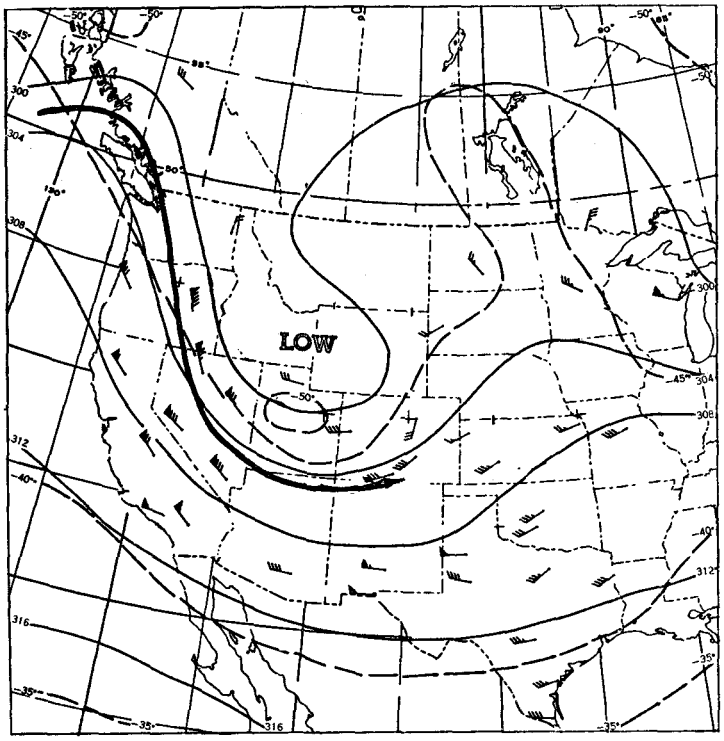

FIGURE 12.—300-mb. chart, 1500 GMT, May 21, 1952.

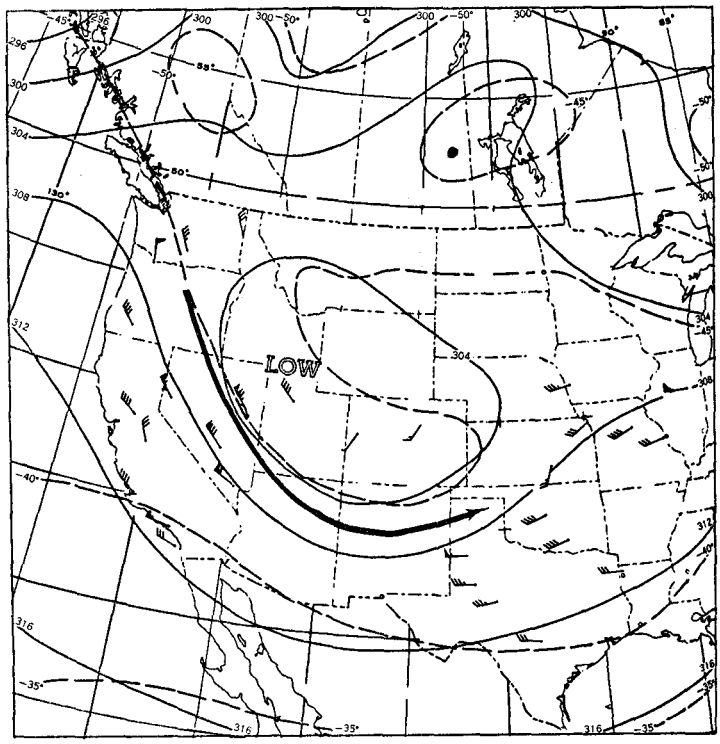

FIGURE 13.—300-mb. chart, 0300 GMT, May 22, 1952.

the trough line and eastward over Colorado, Wyoming, and Montana.

The 300-mb. chart, 1500 GMT May 21 (fig. 12), showed continued warming in the vicinity of Seattle, Wash., accompanied by a 24-hour increase in heights of 600 to 800 gpft. This increase meant a more northerly component to the winds on the west side of the trough. The Pacific jet maximum was located, approximately, over northwestern Nevada and had combined with the old residual jet. When the low center was located just northeast of Salt Lake City, weak divergence of the contours still existed due south of the Low although it was more marked in the southeastern quadrant over New Mexico, Colorado, and Wyoming. The leading edge of the jet showed signs of proceeding through the trough line south of the low center. At the same time an elongation of the jet maximum and a marked decrease in the velocity gradient of the jet was observed. Cooling of the magnitude of 4° to 6° C. occurred to the south of the 300-mb. low center as it moved toward Colorado while temperatures in the northeastern quadrant of the Low rose 3° to 4° C.

On the 0300 GMT 300-mb. chart of the 22d (fig. 13) the jet maximum was centered over north-central Arizona and was quite elongated with the leading edge overshooting the trough line and approaching the Texas Panhandle, which was under the southeastern quadrant of the Low. Height

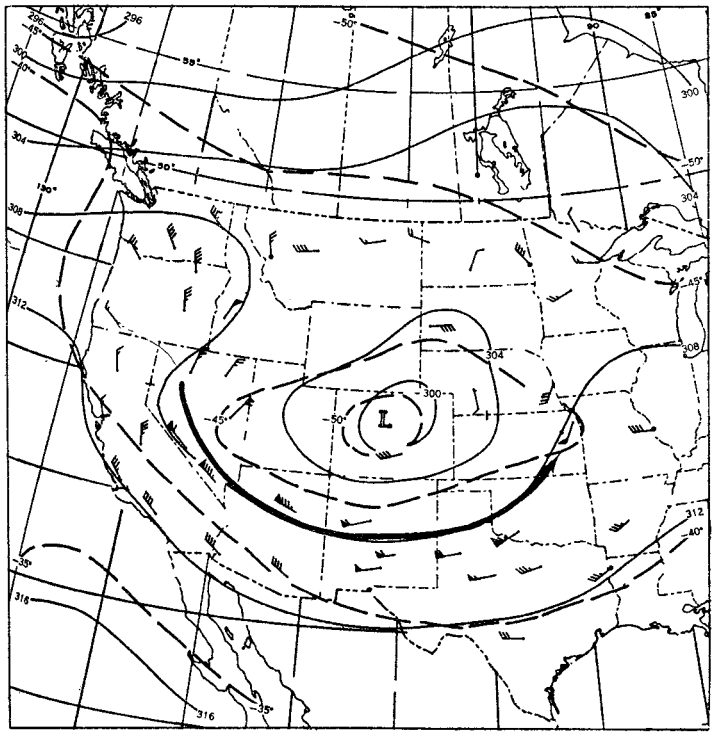

FIGURE 14.—300-mb. chart, 1500 GMT, May 22, 1952.

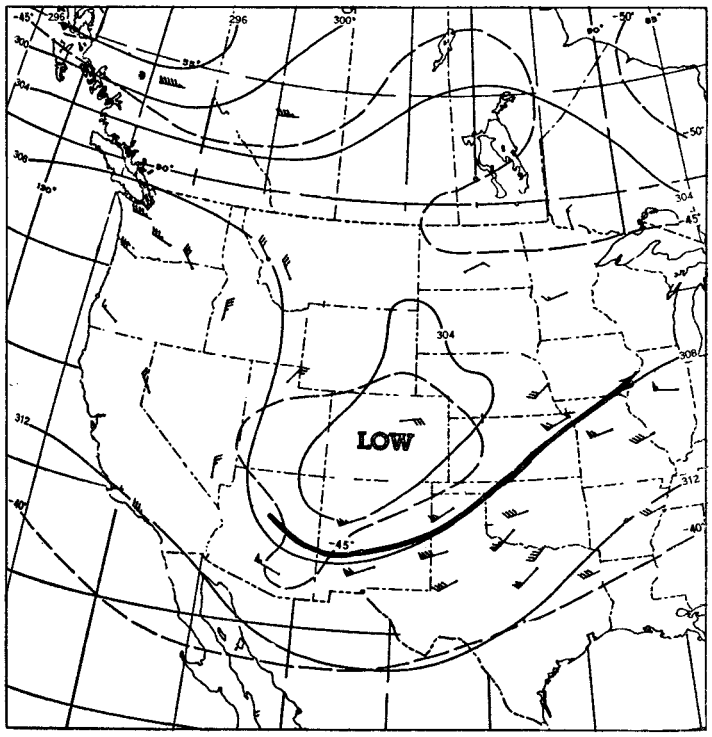

FIGURE 15.—300-mb. chart, 0300 GMT, May 23, 1952.

rises of 200 to 300 gpft. continued along the Oregon coastline with 500- to 600-gpft. rises north of the Low, while at the same time falls of 200 to 300 gpft. were centered over New Mexico. The contour gradient appeared equal in magnitude in the western, southwestern, and southern portions of the Low. Marked weakening of the contour gradient and light winds appeared in the northwestern portion of the Low with the spread of height rises across the northern portion of the low center. The 300-mb. low center itself, moved very slowly eastward into northeastern Utah with the leading edge of cold air at this level in western Colorado.

The 300-mb. chart for 1500 GMT of the 22d (fig. 14) shows no further southward movement of the jet, but rather a continued elongation and curving to south of the path of the upper Low. However, it was becoming more difficult to locate a jet maximum south of the low center. The Low in central Colorado moved slowly eastward across Colorado with a forward velocity of about 10 knots. The region of diffluence (indicated by the contours) had now shifted to eastern Oklahoma and extreme southeastern Kansas while marked weakening of the flow continued upstream in the western and northwestern portions of the Low. Just prior to this map time the precipitation began to diminish in southern Montana and northern Wyoming. The 300-mb. flow (fig. 14) over Montana and Wyoming suggests some convergence in the horizontal, whereas at the surface (fig. 3) this region is in an area of divergence. This is the reverse of the situation when rain fell over the sections of the two States. Once the sinking motion extended from the surface up to fairly high levels the process of vertical motion (upward) was stopped.

On the 0300 GMT 300-mb. chart for the 23d (fig. 15), the jet was advancing eastward into the southeastern quadrant of the Low where it assumed a southwest-northeast orientation as it moved toward the Lake region. Along with the recurvature of the jet there was also a turning of the Low toward the east-northeast. The Low also showed a slight acceleration. After the jet had passed south of the Low, the low-level flow from the south was cut off at about the time of this chart on which can be noted a filling of 300 to 400 gpft. at the Low center aloft.

At 1500 GMT of the 23d, the Low continued to fill and moved into eastern Colorado. About this time the rain, which had continued in extreme southeastern Wyoming, began to end. At 0300 GMT of the 24th, the Low at 300 mb. had filled, leaving little of its former identity in a trough over western Kansas, and the rains ended.

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